

# **ONE PIECE INTERCONNECT FROM CHANNEL CHIP TO HEAD SLIDER IN A VOICE COIL ACTUATOR FOR A DISK DRIVE**

## Cross Reference to Related Applications

This is a divisional application of US Patent Application Number 10/101,809, filed  
5 March 19, 2002, entitled: One Piece Interconnect From Channel Chip to Head Slide.

## Technical field

This invention relates to the interconnection of the read-write head in a head slider to the channel chip in a voice coil actuator used in a disk drive.

## Background Art

10 Disk drives are an important data storage technology, which is based on several crucial components. These components include the interconnection between the read/write heads, which actually communicate with a disk surface containing the data storage medium, and the read/write interfaces of the disk drive. While there has been great progress in disk drives, there are problems, which have yet to be solved.

15 Figure 1A illustrates a typical prior art high capacity disk drive 10 including actuator arm 30 with voice coil 32, actuator axis 40, suspension or head arms 50-58 with slider/head unit 60 placed among the disks.

Figure 1B illustrates a typical prior art high capacity disk drive 10 with actuator 20 including actuator arm 30 with voice coil 32, actuator axis 40, head arms 50-56 and  
20 slider/head units 60-66 with the disks removed.

Since the 1980's, high capacity disk drives 10 have used voice coil actuators 20-66 to position their read/write heads over specific tracks. The heads are mounted on head sliders 60-66, which float a small distance off the disk drive surface when in operation. Often there is one head per head slider for a given disk drive surface. There are usually  
25 multiple heads in a single disk drive, but for economic reasons, usually only one voice coil actuator.

Voice coil actuators are further composed of a fixed magnet actuator **20** interacting with a time varying electromagnetic field induced by voice coil **32** to provide a lever action via actuator axis **40**. The lever action acts to move head arms **50-56** positioning head slider units **60-66** over specific tracks with remarkable speed and accuracy. Actuator arms **30**  
5 are often considered to include voice coil **32**, actuator axis **40**, head arms **50-56** and head sliders **60-66**. Note that actuator arms **30** may have as few as a single head arm **50**. Note also that a single head arm **52** may connect with two head sliders **62** and **64**.

The evolution of disk drives stimulated the computer revolution. While contemporary actuator designs are essential to the progress to date, there remain problems limiting the  
10 reliability and capability of disk drives built with contemporary voice actuators. One problem has to do with the method of electrically interconnecting heads to the head interface electronics.

Figure 2 illustrates a simplified circuit diagram of a disk drive controller Printed Circuit Board (PCB) **1000**, with channel interface **1140** controlling MR read/write heads **200-206**  
15 of the prior art, using connector **226**, flex circuits **224** and **210-216**, as well as actuator PCB **220**.

Disk drive controller Printed Circuit Board (PCB) **1000** includes computer **1100** interacting with channel interface **1140**. Channel controller **1140** controls read-write preamplifier **222**, which communicates using separate read differential signal pairs (**r+** and **r-**) and write differential signal pairs (**w+** and **w-**) with the MR read/write heads **200-206**.  
20

Note that connector **226** mechanically couples **1150** with connector **230** to electrically couple channel interface **1140** through read-write preamplifier **222** to MR read-write head **200**.

25 Note also that different prior art disk drives may have only one MR read-write head **200**, or more than one MR read-write heads (**202-206**).

The interconnection between MR read-write head **200**, preamplifier **222** and connection **226**, begins at head slider **60** and involves several distinct circuits which must be soldered

together to provide this interconnection. Today, the actuator PCB 220 is connected to separate flex circuits coupling to connector 226 as well as separate flex circuits 210-216, coupling to MR read-write heads 200-206, respectively.

Computer 1100 within embedded disk controller PCB 1000 receives readings of the spin  
5 valve voltage  $V_{rd}$  from an analog read/write interface including channel interface 1140 coupled 1152-230-1150-226-224 to read-write preamplifier 220. Computer 1100 also controls the read current  $Ir\_set$  for read differential signal pair r+ and r-, as well as the write current  $Iw\_set$  for write differential signal pair w+ and w-.

Coupling 1152 usually involves printed circuit board traces to connector 230. Coupling  
10 1150 indicates the mechanical coupling of connector 230 to connector 226. Connector 226 couples via flex circuit 224 with read-write preamplifier 222 through actuator PCB 220.

Read-write preamplifier 220 couples through actuator PCB 220 via flex circuit 210 to MR read-write head 200. Read-write preamplifier 220 couples through actuator PCB 220 via flex circuit 212 to MR read-write head 202. Read-write preamplifier 220 couples through actuator PCB 220 via flex circuit 214 to MR read-write head 204. Read-write preamplifier 220 couples through actuator PCB 220 via flex circuit 216 to MR read-write head 206.

The process of reading the data storage surface using MR read/write head 200 includes  
20 the following. Computer 1100 accesses 1122 a memory 1120. Memory 1120 contains program system 1128. Memory 1120 typically includes a non-volatile memory component. This non-volatile memory component is often used to store program system 1128.

Figures 3A, 3B, 3C and 3D illustrate a prior art actuator arm from the top view, detailed  
25 portion of top view, side view and front views, respectively.

Figure 3A illustrates a top view of a prior art actuator arm 30 showing head arm 50, actuator axis 40, and head slider 60 of Figure 1 with detail region 70 illustrated in Figure 3B.

Figure 3B illustrates a top view of detail region 70 of Figure 3A.

Figure 3C illustrates a side view of part of detail region 70 of Figure 3B indicating the interconnections 74-80 via various head sliders as found in the prior art. Each of these labeled interconnections includes two pairs of differential signals. One differential signal

- 5 pair interconnects a read head to a read interface of the disk drive. The other differential signal pair interconnects a write head to a disk drive write interface.

Figure 3D illustrates a different perspective on Figure 3C, illustrating that these signal interconnections 74 may be embodied as various forms of cables attached to a head arm, including flex and ribbon cables.

- 10 Figure 3E illustrates an alternative prior art electrical interconnection scheme for 74-80 traversing along head arm 50, essentially parallel to head arm 50.

Figure 3E is typical of prior art uses of flex circuitry to interconnect head sliders and disk read/write interfaces. Four individual traces are used for the read differential signal pair (R+, R-) and the write differential signal pair (W+, W-).

- 15 The prior art teaches interconnecting multiple pieces of interconnection circuitry 224, 220, and 210 between the read-write head 200 in the head slider 60 and channel interface 1140 coupling 226. Assembling these interconnection circuits with these multiple flex circuits usually includes reflow bonding and/or ultra-sonic bonding of these flex circuits.

- 20 Figure 4 illustrates a prior art method 1500 of making the interconnection circuit from a read-write head 200 to embedded disk controller PCB connector 226.

Arrow 1510 directs the flow of execution from starting operation 1500 to operation 1512. Operation 1512 performs bonding read-write head 200 to flex circuit 210. Arrow 1514 directs execution from operation 1512 to operation 1516. Operation 1516 terminates the operations of this flowchart.

- 25 Arrow 1520 directs the flow of execution from starting operation 1500 to operation 1522. Operation 1522 performs bonding flex circuit 210 to actuator PCB 220. Arrow 1524

directs execution from operation **1522** to operation **1516**. Operation **1516** terminates the operations of this flowchart.

Arrow **1530** directs the flow of execution from starting operation **1500** to operation **1532**.

Operation **1532** performs bonding electronic components including at least read-write

5 preamplifier **222** to actuator PCB **220**. Arrow **1534** directs execution from operation **1532** to operation **1516**. Operation **1516** terminates the operations of this flowchart.

Arrow **1540** directs the flow of execution from starting operation **1500** to operation **1542**.

Operation **1542** performs bonding flex circuit **224** to actuator PCB **220**. Arrow **1544**

directs execution from operation **1542** to operation **1516**. Operation **1516** terminates the

10 operations of this flowchart.

Arrow **1550** directs the flow of execution from starting operation **1500** to operation **1552**.

Operation **1552** performs bonding flex circuit **224** to connector **226**. Arrow **1554** directs

execution from operation **1552** to operation **1516**. Operation **1516** terminates the

operations of this flowchart.

15 The prior art teaches several interconnection circuit variations, including three interconnection circuits as discussed above, as well as some examples of two interconnection circuits. The three interconnection circuit scheme contents are referred to as main flex (actuator PCB **220**), bridge flex circuit (**224**) and suspension flexure (**210-216**). The two interconnection circuits are found in two variations. The first variation  
20 contains a main flex circuit (**224** plus **220**) and suspension flexure (**210-216**). The second variation contains a main flex circuit (**220**) and a combined bridge flex circuit with suspension flexure (**224** plus **210-216**).

In any of the prior art approaches, multiple interconnection circuits are typically bonded together to create electrical couplings using either an ultrasonic bonding process or a

25 reflow bonding process to create the interconnection circuit between connector **226**, read-write preamplifier **222**, and one or more MR read-write heads **200-206**.

While this method of interconnection has achieved widespread production use in the manufacture of disk drives, it has some problems due to the employed bonding process.

Reflow bonding processes apply heat to a solder paste or solid to form a solder joint. The paste or solid is melted, and then allowed to cool to create the solder joint. Ultrasonic bonding processes use ultrasonic energy to form a solder joint at essentially room temperature. Each of these bonds increases parasitic capacitance as well as increases 5 parasitic inductance on the bonded line. Each bonding step increases the manufacturing cost for the interconnection circuit, and consequently, for the voice coil actuators and, ultimately, for the disk drives containing these interconnection circuits.

What is needed is an interconnection circuit minimizing the number of wire bonds on each line. What is further needed is a method of making the interconnection circuit which 10 minimizes the number of bonding steps required to make the interconnections between MR read-write heads, preamplifier and connector.

#### Summary of the invention

The invention solves at least all the needs discussed in the prior art. The invention includes an interconnection circuit minimizing the number of wire bonds on each line. 15 The invention further includes a method of making the interconnection circuit minimizing the number of bonding steps required to make the interconnections between the MR read-write heads, the preamplifier and the connector.

A single flex interconnection circuit **2000** bonds to connector **226**, electronic components including at least preamplifier **222** and at least one MR read-write head **200** (see Figure 20 **5**). Flex interconnection circuit **2000** provides the least number of bonds for each of the lines involved. The invention includes the flex interconnection substrate with bonding sites for connector **226**, electronic components and MR read-write heads.

The method **3000** (see Figure **6A**) of making flex interconnection circuits **2000** involves the least number of bonding steps necessary to provide interconnection between 25 connector **226**, electronic components including preamplifier **222** and at least one MR read-write head **200**. The bonded electronic components may include one or more resistors as well as one or more capacitors. Note that more than one MR read-write head

(200-206) may be bonded to flex interconnection circuit 2000 in one operation 3032 of Figure 6A.

Alternatively, a method 3300 (Figure 7) coupling connector 226, preamplifier 222 and several MR read-write heads (200-206) may apply the method 3000 of Figure 6A to 5 interconnect the first MR read-write head 200 and then successively bond other MR read-write heads in operations 3322, 3332, and 3342 of Figure 7.

The invention includes a method 3500 (Figure 8) of assembling an actuator using flex interconnection circuit 2000. The invention further includes actuators as the product of the process making them from flex interconnection circuits 2000. The invention includes 10 disk drives made from the process of assembling the inventive actuators into the disk drives.

Both the actuators and disk drives show improved reliability and noise suppression characteristics from minimized number of bonds per line in flex interconnection circuit 2000. Both the actuators and disk drives cost less to manufacture, because of the reduced 15 manufacturing cost of flex interconnection circuit 2000.

These and other advantages of the present invention will become apparent upon reading the following detailed descriptions and studying the various figures of the drawings.

#### Brief Description of the Drawings

Figure 1A illustrates a typical prior art high capacity disk drive 10 including actuator arm 20 with voice coil 32, actuator axis 40, suspension or head arms 50-58 with slider/head unit 60 placed among the disks;

Figure 1B illustrates a typical prior art high capacity disk drive 10 with actuator 20 including actuator arm 30 with voice coil 32, actuator axis 40, head arms 50-56 and slider/head units 60-66 with the disks removed;

25 Figure 2 illustrates a simplified circuit diagram of a disk drive controller Printed Circuit Board (PCB) 1000, with channel interface 1140 controlling MR read/write heads 200-206

of the prior art, using connector 226, flex circuits 224 and 210-216, as well as actuator PCB 220;

Figure 3A illustrates a top view of a prior art actuator arm 30 showing head arm 50, actuator axis 40, and head slider 60 of Figure 1 with detail region 70 illustrated in Figure 5 3B;

Figure 3B illustrates a top view of detail region 70 of Figure 3A;

Figure 3C illustrates a side view of part of detail region 70 of Figure 3B indicating the interconnections 74-80 via various head sliders as found in the prior art;

Figure 3D illustrates a different perspective on Figure 3C, illustrating that these signal interconnections 74 may be embodied as various forms of cables attached to a head arm, including flex and ribbon cables;

Figure 3E illustrates an alternative prior art electrical interconnection scheme for 74-80 essentially parallel to head arm 50;

Figure 4 illustrates a prior art method 1500 of making the interconnection circuit from a read-write head 200 to embedded disk controller PCB connector 226;

Figure 5 illustrates a single flex interconnect circuit 2000 providing interconnection between connector 226 via preamplifier 222 and MR read-write head 200;

Figure 6A illustrates a method 3000 for making flex interconnection circuit 2000, coupling connector 226 through preamplifier 222 with MR read-write head 200;

20 Figure 6B illustrates a detail flowchart of operation 3022 of Figure 6A for bonding electronic components to flex interconnection circuit 2000;

Figure 7 illustrates a method 3300 for making an interconnection circuit, coupling connector 226 through preamplifier 222 with at least two MR read-write heads using the method 3000 of Figure 6A; and

Figure 8 illustrates a method 3500 for assembling a voice coil actuator using an interconnection circuit as the product of the method 3000.

#### Detailed Description of the Invention

The invention includes an interconnection circuit minimizing the number of wire bonds on each line. The invention further includes a method of making the interconnection circuit minimizing the number of bonding steps required to make the interconnections between MR read-write heads, preamplifier and connector.

Figure 5 illustrates a single flex interconnect circuit 2000 providing interconnection between connector 226 via preamplifier 222 and MR read-write head 200.

Note that Figure 5 also illustrates a an alternative schematic view of flex interconnection substrate 2000 with bonding sites for connector 226, preamplifier 222 and MR read-write head 200.

A single flex interconnection circuit 2000 bonds to connector 226, electronic components including at least preamplifier 222 and at least one MR read-write head 200. Flex interconnection circuit 2000 provides the least number of bonds for each of the lines involved.

The invention includes the flex interconnection substrate with bonding sites for connector 226, electronic components and MR read-write heads. The electronics components include at least a preamplifier 222.

The electronics component collection may further include at least one capacitor. The electronics component collection may also further include at least one resistor.

Flex interconnection circuit 2000 includes a flex interconnection substrate with the following bonding to the substrate: connector 226, an electronics component collection including at least preamplifier 222 and at least one MR read-write head. The bonding of each of these is done at a specific bonding site. As will be apparent to one of skill in the art, when multiple MR read-write heads are being bonded, there are separate, though similar, bonding sites for each of the MR read-write heads.

Figure 3F illustrates a schematic view of a preferred bonding site for connector 226. Figure 3G illustrates a schematic view of a preferred bonding site for an electronic components collection including preamplifier 222, two capacitors C1 and C2, as well as, resistor R1. Figure 3H illustrates a schematic view of a preferred bonding site for MR read-write head 200.

The flex interconnection circuit 2000 couples connector 226 with preamplifier 222 through the bonding of connector 226 and preamplifier 222 to the flex interconnection substrate.

It is preferred that preamplifier 222 support a coupled communication via connector 226

10 based upon the following pin-out from reading Figure 3F bonding site for connector 226 from left to right, top row of pins on the

VC+	VC-
GND	GND
GND	VSS(-5V)
FLT/DBHY/TEMP	VDD(+5V)
GND	WDY
MRB/FAST	wdx
SCLK	SDATA
R/W	SDEN
No Connect	RDY
WSRV/ABHV	RDX

Table One illustrates a preferred pinout for connector 226 providing a coupling to preamplifier 222.

Preamplifier **222** may preferably be the 81G5014 integrated circuit manufactured by Marvell Semiconductor. The capacitance of **C1** and **C2** may preferably be 0.01 micro-Farads to within acceptable tolerances. The resistance of **R1** may preferably be 12.4K Ohms to within acceptable tolerances. Each of these electronics component collection members is preferably packaged in a surface mount compatible package.

The flex interconnection circuit **2000** couples preamplifier **222** with MR read-write head **200** through the bonding of preamplifier **222** and MR read-write head **200** to the flex interconnection substrate. Figure **3H** illustrates a preferred bonding site for MR read-write head **200**.

Figure **3I** illustrates a preferred cross section view of the read differential signal pair **r-** and **r+** and the write differential signal pair **w+** and **w-** of the flex interconnection substrate coupling a MR read-write head bonding site with the preamplifier bonding site.

The preferred base thickness beneath these signal pairs is from 15 to 25 micrometers, with a preferred overlay above the signal pairs from 5 to 33 micrometers. The preferred read trace width is from 100 to 125 micrometers, with preferred spacing between the read differential signals from 40 to 75 micrometers. The preferred spacing between the read and write differential signal pairs is from 100 to 170 micrometers. The preferred write signal width is from 100 to 125 micrometers. The preferred spacing between write differential signals is from 40 to 75 micrometers.

While the read and write differential signal traces may be made from several metals including copper, aluminum, silver and gold, the preferred composition is copper, with a gold trace at the bonding sites of the MR read-write heads.

Figure **6A** illustrates a method **3000** for making flex interconnection circuit **2000**, coupling connector **226** through preamplifier **222** with MR read-write head **200**.

Arrow **3010** directs the flow of execution from starting operation **3000** to operation **3012**. Operation **3012** performs bonding connector **226** to flex interconnection circuit **2000**. Arrow **3014** directs execution from operation **3012** to operation **3016**. Operation **3016** terminates the operations of this flowchart.

Arrow **3020** directs the flow of execution from starting operation **3000** to operation **3022**. Operation **3022** performs bonding electronic components including at least read-write preamplifier **222** to flex interconnection circuit **2000**. Arrow **3024** directs execution from operation **3022** to operation **3016**. Operation **3016** terminates the operations of this flowchart.

Arrow **3030** directs the flow of execution from starting operation **3000** to operation **3032**. Operation **3032** performs bonding at least one MR read-write head to flex interconnection circuit **2000**. Arrow **3034** directs execution from operation **3032** to operation **3016**. Operation **3016** terminates the operations of this flowchart.

10 As will be apparent to one of skill in the art, when more than one MR read-write head is involved, it is often preferable to bond them all concurrently to the flex interconnection substrate through operation **3032**.

Figure **6B** illustrates a detail flowchart of operation **3022** of Figure **6A** for bonding electronic components to flex interconnection circuit **2000**.

15 Arrow **3060** directs the flow of execution from starting operation **3022** to operation **3062**. Operation **3062** performs bonding read-write preamplifier **222** to flex interconnection circuit **2000**. Arrow **3064** directs execution from operation **3062** to operation **3066**. Operation **3066** terminates the operations of this flowchart.

Bonding electronic components to flex interconnect circuit **2000** may further include at  
20 least one of the following operations of Figure **6B**.

Arrow **3070** directs the flow of execution from starting operation **3022** to operation **3072**. Operation **3072** performs bonding at least one resistor to flex interconnection circuit **2000**. Arrow **3074** directs execution from operation **3072** to operation **3066**. Operation **3066** terminates the operations of this flowchart.

25 Arrow **3080** directs the flow of execution from starting operation **3022** to operation **3082**. Operation **3082** performs bonding at least one capacitor to flex interconnection circuit

**2000.** Arrow **3084** directs execution from operation **3082** to operation **3066**. Operation **3066** terminates the operations of this flowchart.

Figure 7 illustrates a method **3300** for making an interconnection circuit, coupling connector **226** through preamplifier **222** with at least two MR read-write heads using the method **3000** of Figure 6A.

5 Arrow **3310** directs the flow of execution from starting operation **3300** to operation **3312**. Operation **3312** performs applying the method **3000** to make the flex interconnection circuit coupling connector **226** through preamplifier **222** to first MR read-write head **200**. Arrow **3314** directs execution from operation **3312** to operation **3316**. Operation **3316** 10 terminates the operations of this flowchart.

Arrow **3320** directs the flow of execution from starting operation **3300** to operation **3322**. Operation **3322** performs bonding a second MR read-write head **202** to the flex interconnection circuit **2000** to provide the coupling of connector **226** through preamplifier **222** to the second MR read-write head **202**. Arrow **3324** directs execution 15 from operation **3322** to operation **3316**. Operation **3316** terminates the operations of this flowchart.

The method **3300** may further include the following operations of Figure 7.

Arrow **3330** directs the flow of execution from starting operation **3300** to operation **3332**. Operation **3332** performs bonding a third MR read-write head **204** to the flex 20 interconnection circuit **2000** to provide the coupling of connector **226** through preamplifier **222** to the third MR read-write head **204**. Arrow **3334** directs execution from operation **3332** to operation **3316**. Operation **3316** terminates the operations of this flowchart.

Arrow **3340** directs the flow of execution from starting operation **3300** to operation **3342**. Operation **3342** performs bonding a fourth MR read-write head **206** to the flex 25 interconnection circuit **2000** to provide the coupling of connector **226** through preamplifier **222** to the fourth MR read-write head **206**. Arrow **3344** directs execution

from operation **3342** to operation **3316**. Operation **3316** terminates the operations of this flowchart.

Figure **8** illustrates a method **3500** for assembling a voice coil actuator using the product of the method **3000**.

- 5 Arrow **3510** directs the flow of execution from starting operation **3500** to operation **3512**. Operation **3512** performs affixing to a head slider **60** a MR read-write head **200** bonded to the flex interconnection circuit **2000** made with the method **3000** to create a head arm **50** in an actuator **30**. Arrow **3514** directs execution from operation **3512** to operation **3516**. Operation **3516** terminates the operations of this flowchart.
- 10 Arrow **3520** directs the flow of execution from starting operation **3500** to operation **3522**. Operation **3522** performs anchoring the flex interconnection circuit **2000** about the preamplifier **222** to the actuator **30**. Arrow **3524** directs execution from operation **3522** to operation **3516**. Operation **3516** terminates the operations of this flowchart.
- 15 Arrow **3530** directs the flow of execution from starting operation **3500** to operation **3532**. Operation **3532** performs binding the flex interconnection circuit **2000** to the head arm **50** between the preamplifier **222** and the MR read-write head **200**. Arrow **3534** directs execution from operation **3532** to operation **3516**. Operation **3516** terminates the operations of this flowchart.

The preceding embodiments have been provided by way of example and are not meant to

20 constrain the scope of the following claims.